IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/717,387	Confirmation No. 7470
Applicant	:	Thomas W. Stone	
Filed	:	November 18, 2003	
TC/A.U.	:	2613	
Examiner	:	Thi Q. Le	
Title	:	OPTICAL ADD/DROP MULTIPLEXING SYSTEMS	
Docket No.	:	10010931-1	
Customer No.	:	057299	

To: Commissioner of Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 CFR 1.131

Sir:

I, Orlando Lopez, declare that:

1. I was one of the patent attorneys who prepared the above-referenced patent application.

2. Prior to July 23, 2002, the assignee, Wavefront Research, Inc., contacted the law firm of Perkins Smith & Cohen LLP and requested them to file a patent application on the Invention Disclosure No. 6536-123(copies attached with dates deleted).

3. At least three draft patent applications were generated by me and Attorney Erlich for review and revision (comments) by the inventor, Thomas W. Stone, just prior to July 23, 2002 to November 4, 2003, at which date the application was filed in the U.S. Patent and Trademark Office.

4. Each draft patent application improved upon the prior draft until the inventor, Thomas W. Stone, approved the final draft for filing as a patent application.

5. During part of the period from just prior to July 23, 2002 to November 4, 2003, I worked on at least 10 other cases having Dr. Thomas W. Stone as an inventor and the same assignee as the above referenced patent application and relating to similar technology. The cases that Docket numbers 28579 – 122, 128, 125, 131 136, 144, 145, 146 (the above referenced patent application had Docket number 28579- 123).

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I even further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Orlando Lopez

1-16-07
Date

INVENTION DISCLOSURE

WAVEFRONT RESEARCH INC.

FILE COPY

Disclosure Number: W-6536-123

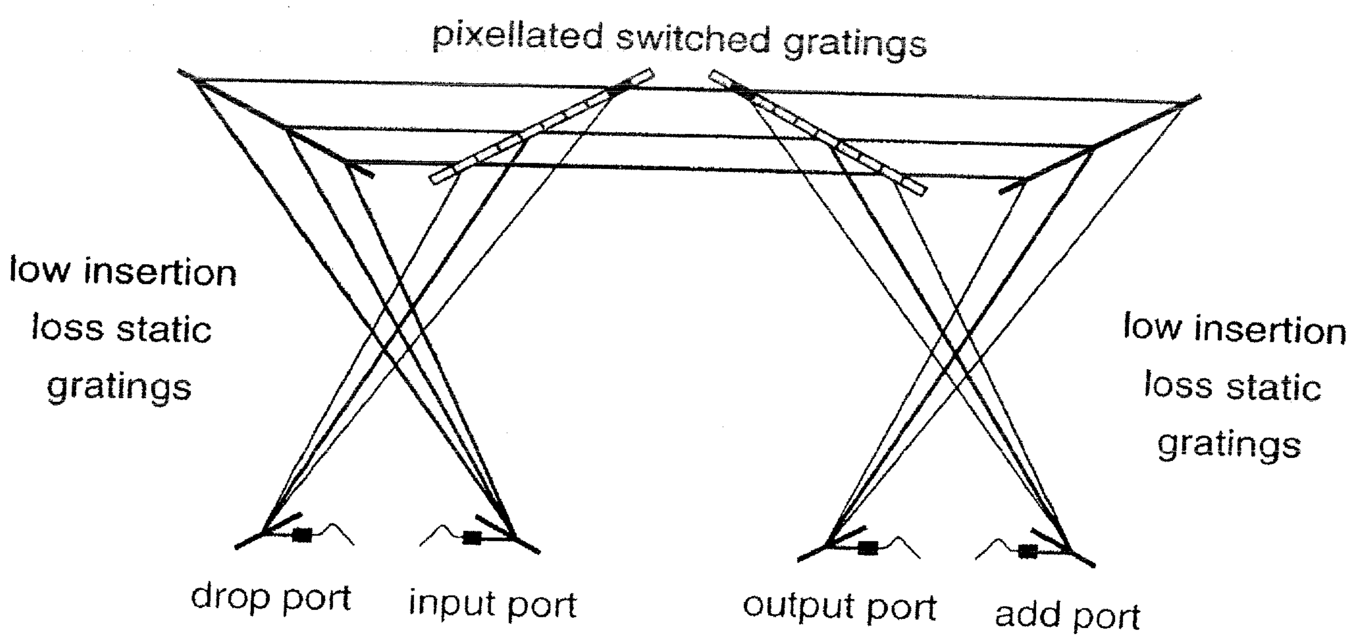
Title of Invention: Optical Add/Drop Systems

Inventor(s): Thomas W. Stone

Address(es): Hellertown, PA

I. Description of Invention

The present invention provides a free space optical multiplexing, demultiplexing, and add/drop multiplexing device that is suitable for adding, dropping, or modifying signals that are wavelength multiplexed onto a common optical path. This device, for example, is suitable for Wavelength Division Multiplexing (WDM) and Dense Wavelength Division Multiplexing (DWDM) applications. One such add/drop system configuration is shown below.



The incorporation of free space switching in the present invention has several distinct advantages over past multiplexing techniques. More specifically, these advantages include the potential for lower insertion loss, superior switch isolation, multiple reflection and crosstalk suppression, and less complexity.

Detailed Description of the Invention

Reference is now made to Figure 1 of the attached drawings which illustrates the broad concept of the invention in schematic fashion, thereby presenting an overview of the optical add/drop multiplexing system of the present invention in one of numerous embodiments, the other embodiments being set forth below with respect to the remaining figures.

One embodiment of the optical time shifter and routing system 10 of this invention is illustrated in Figure 1 of the drawings and includes static (non-switchable) diffraction gratings 12, 14, 16, 18, 20, and 22 and switchable grating 30. In the configuration of Figure 1, each of these gratings is parallel to each other, and base gratings 12, 14, 16, and 18 have identical spatial grating frequencies. Similarly, the grating spatial frequencies of the vertex gratings 20, 22, and 30 are also identical, but the vertex gratings have higher gratings spatial frequencies than the base gratings, such that the light diffracted by the base gratings is symmetrically diffracted from the vertex gratings and recombined at the subsequent base gratings. For example, in system 10 of Fig. 1, the vertex gratings 20, 22, and 30 have twice the spatial frequency of the base gratings 12, 14, 16, and 18. Base gratings 12 and 18 are located symmetrically with respect to vertex grating 20. Similarly base gratings 16 and 14 are located symmetrically with respect to vertex grating 22. The switchable grating 30 is located at the intersection of the two base-vertex arrangements described above as illustrated in Fig. 1. The switchable grating 30 is further divided into individually switchable segments or pixels 32. These individually switchable segments can be formed, for example, by pixellating the electrode controlling the grating. Electronic control 34 provides the individual control signals, which switch the individual grating segments.

Elements of the operation of the add/drop multiplexer of Fig. 1 can now be described. Input free-space beam 40 is typically a collimated or nearly collimated beam of electromagnetic radiation that may consist of a multiplicity of optical signals each of which are modulated on wavelength-multiplexed optical carriers 50 that each have differing center wavelengths. Beams guided in waveguides or optical fibers 42 may be converted into or from free space beams through the use of lenses 44. The lens 44 may be refractive, diffractive, or gradient index, or a combination thereof in nature. Input beam 40 is incident normally on grating 12 (perpendicularly with respect to the surface of the grating 12) at a single spatial location. Base diffraction grating 12 angularly disperses the input beam 40 into separate beams each of which contains distinct modulated optical carriers 50. In general the optical carriers with longer wavelengths are diffracted by grating 12 through larger angles, such that the longest wavelength optical carrier 52 is incident on grating 20 at a higher location than mid-wavelength optical carrier 54, which is in turn incident on grating 20 at a higher location than shortest wavelength optical carrier 56. In such fashion each of the optical carriers 50 are incident at distinct spatial locations on the vertex gratings 20, 22, and 30.

Finally, switched grating 30 is placed symmetrically in the region where the optical carrier beams 70, 72, 76, and 74 intersect as shown in Fig. 1. Further, the size scale of the multiplexer 10 and width of beams 60, 60, 62, and 64 is chosen such that the individual optical carriers of differing center wavelengths are spatially separated on the vertex elements 20, 22, and 30. This provides for a switchable grating segment or pixel along each of optical carrier beams 70 such that for each such beam in optical carrier group 70, if the intersecting segment of grating 30 is switched "off", the beam in optical carrier group 70 is transmitted through grating 30 becoming a beam in optical carrier group 72; and if the segment is switched "on" the beam is diffracted and becomes a beam in optical carrier group 74. Each of the beams in the optical carrier groups represent modulated optical carriers with different center wavelengths, and corresponding beams in optical carrier groups 70, 72, 76, and 74 (defined by

intersections at a common grating segment of grating 30) represent modulated optical carriers of a particular center wavelength.

Consider the case of all segments of the switched grating 30 in the "off" state, in which case all light incident on grating 30 is transmitted, as if grating 30 did not exist. All optical carriers 50 are initially spatially overlapping on a single spot and are normally incident on base grating 12 from beam 40. Because of the symmetric location of vertex grating 20 with respect to base gratings 12 and 18 and the grating frequency relationship described earlier, all optical carriers 50 are angularly diverging toward vertex grating 20 and are spatially separated on vertex grating 20 where they are diffracted symmetrically into optical carrier beams 70 which are converging toward a single spot or location on base grating 18. As these optical carrier beams 70 are transmitted through "off" grating 30, they are transmitted into optical carrier beams 72. When these optical carriers 72 are incident on grating 18, they are all diffracted symmetrically back into a single beam 64 in which all differing wavelength optical carriers propagate in a singe beam with identical propagation directions. This beam 64 may then readily be coupled into an optical fiber or waveguide 42 using lens 44. Thus, with all switched grating pixels 32 switched off, all the wavelength multiplexed signals in input beam 40 are spatially separated and then recombined in a wavelength multiplexed beam 64.

Still further consider the case where all segments of the switched grating pixels 32 of switched grating 30 are in the "off" state (i.e., are transparent), in which case all light incident on grating 30 is transmitted, as if grating 30 did not exist. Base gratings 16 and 14 are located symmetrically with respect to vertex grating 22. All optical carriers 76 are initially spatially overlapping on a single spot on base grating 16 and are normally incident on base grating 16 from beam 62. Because of the symmetric location of vertex grating 22 with respect to base gratings 16 and 14 and the grating frequency relationship described earlier, all optical carriers 76 after diffraction by base grating 16 are angularly diverging toward vertex grating 22. As these optical carrier beams 76 are transmitted through "off" grating 30, they become optical carriers 74, and are spatially

separated on vertex grating 22 where they are diffracted symmetrically into optical carriers 78 which converge toward a single spot or location on base grating 14. When these optical carriers 78 are incident on grating 14, they are all diffracted symmetrically back into a single beam 60 in which all differing wavelength optical carriers propagate in a singe beam with identical propagation directions. This beam 60 may then readily be coupled into an optical fiber or waveguide 42 using lens 44. Thus, with all switched grating pixels 32 switched off, all the wavelength multiplexed signals in input beam 62 are spatially separated and then recombined in a wavelength multiplexed beam 60.

Due to the symmetric nature of Volume Bragg diffraction gratings, a dual mapping occurs simultaneously with optical carrier beams 76 incident on the switched grating 30 with respect to the optical carrier beams 70 incident on the switched grating 30 as described above. Therefore, if all the switchable grating segments 32 are "off", Optical carriers 70 are transmitted into optical carriers 72, and optical carriers 76 are transmitted into optical carriers 74. In this case, all the wavelength multiplexed carriers (and the signals they carry) that are input in beam 40 are output in beam 64; and all the wavelength multiplexed carriers (and the signals they carry) that are input in beam 62 are output in beam 60. Alternately, if all the switchable grating segments 32 are "on", optical carriers 70 are diffracted into optical carriers 74, and optical carriers 76 are diffracted into optical carriers 72. In this latter case, all the wavelength multiplexed carriers (and the signals they carry) that are input in beam 40 are output in beam 60; and all the wavelength multiplexed carriers (and the signals they carry) that are input in beam 62 are output in beam 64.

Since the individual optical carriers (each with a unique center wavelength) are spatially resolved on switched grating 30 and are each incident on a unique switched grating pixel of group 32, the route of each wavelength multiplexed signal in beams 40 and 62 may be individually controlled by setting the state of the corresponding grating pixel such that it is output in either of beams 64 or 60. Each of the beams in one of the optical carrier groups represent modulated optical carriers with different center wavelengths, and corresponding beams in optical carrier groups 70, 72, 76, and 74

(defined by intersections at a common grating segment of grating 30) represent modulated optical carriers of a common particular center wavelength. Accordingly, for each beam in optical carrier group 76, if the intersecting segment of grating 30 is switched "off", the beam in optical carrier group 76 is transmitted through grating 30 becoming a beam in optical carrier group 74 and is ultimately included in output beam 60; in addition, if the input beam 40 contains an optical carrier of the same center wavelength as the beam of optical carrier group 76 described above, it will be transmitted through the same "off" pixel and output in beam 64. If this same segment of switched grating 30 described above is switched "on", the corresponding optical carriers (if present) from inputs 40 and 62 will be diffracted and output in beams 60 and 64, respectively.

The operation of the wavelength add/drop multiplexer 10 can now be described with the help of Figure 2. For convenience the beams 40, 60, 62, and 64 are also described as input, output, add, and drop ports, respectively.
Consider the wavelength division multiplexed (WDM) scenario where the input, output, add, and drop ports or beams 40, 60, 62, and 64, respectively, each may contain many wavelength multiplexed optical carriers propagating as single multiplexed beams which are incident at the respective single port locations. Each of these wavelength multiplexed optical carriers may be modulated with one or more signals. It is conventional in the wavelength division multiplexed (WDM) scenario to universally name each of the many possible WDM channels, each of which are defined by a particular center wavelength. These WDM channels have two states: either the WDM channels are "populated" and contain an optical carrier of the center wavelength defined for the WDM channel, or they are "empty" WDM channels which do not contain an optical carrier. The optical carrier in a given WDM channel may be "dropped" or removed, thus leaving the WDM channel empty. Alternatively, an empty WDM channel can have an optical carrier "added" in which case it is then populated.

For the purpose of illustrating the function of the add/drop multiplexer 10 of Figure 2, three of the many possible named WDM channels 80, 90, and 100 are illustrated. WDM

channel 80 is defined by the wavelength used in the longest wavelength optical carrier 52. WDM channel 90 is defined by the wavelength used in the mid-wavelength optical carrier 54. WDM channel 90 is defined by the wavelength used in the longest wavelength optical carrier 56. All WDM beams contain the same named WDM channels, including WDM channels 80, 90, and 100. Input beam 40 in figure 2 contains carrier 52 in WDM channel 80, carrier 54 in WDM channel 90, and no optical carrier in WDM channel 100. In figure 2, empty WDM channels are represented by dashed lines, and populated WDM channels are represented by solid lines.

Figure 2 illustrates a the case of particular settings of Add/Drop Multiplexer 10 in which the switched grating pixel 110 corresponding to WDM channel 80 is switched "on"; the switched grating pixel 115 corresponding to WDM channel 90 is switched "off"; and the switched grating pixel 120 corresponding to WDM channel 100 is switched "off". With these settings it is shown below that Carrier 52 is transmitted from input port 40 to output port 60; carrier 54 is dropped from input port 40 to drop port 64; and carrier 57 is added from add port 62 to output port 60. These three cases illustrate the basic functionality of the add/drop system 10.

Each of the segments 32 on switched grating 30 are used to control the passage, addition, or dropping of particular modulated optical carriers.

The switched gratings used in the configurations described above may be fabricated using many technologies. In a preferred embodiment, the switchable gratings may be formed using Polymer Dispersed Liquid Crystal volume holographic gratings which can be fabricated with very low insertion loss (e.g., 0.2-0.3 dB/grating) and fast switching times (e.g., tens to hundreds of microseconds). In another aspect of the present invention, the same PDLC switchable gratings preferred for use in these devices can be used for the static non-switchable gratings that are also used in these devices. Accordingly, the electrodes used to apply electric fields to switch the switchable gratings are simply omitted from the gratins for the non-switchable gratings.

In such fashion all the advantages of low insertion loss, high diffraction efficiency, low scatter, etc. of the switchable gratings can be provided for the non-switchable gratings, and the performance is further enhanced since the absorption and surface reflection losses induced by the transparent electrodes are eliminated in the non-switchable gratings. This principle is also applicable to other forms of switchable holographic elements in including lenses, mirrors, and corrector plates.

Figures 3-12 illustrate system variations that are readily understood using the above principles. Figure 13 illustrates a low loss wavelength multiplexing and demultiplexing configuration using non-switched gratings. Finally, Figure 14 illustrates a combined add/drop and multiplexing configuration, where the cascade of upper gratings would typically be switched, pixellated gratings as described earlier.

II. Circumstances of Invention and Sponsors

This invention was made during unsponsored WRI time. This invention was not made under any government contract support.

III. Date of Conception

This invention was conceived on and following [redacted]

IV. Signatures

Signature(s) of Inventor(s):

Signature	Name (print)	Date
Thomas W. Stone	THOMAS W. STONE	[redacted]

Witness:

The above confidential/proprietary information is read and understood by:

Signature	Name (print)	Date
Michelle M Stone	Michelle M Stone	[redacted]

Fig. 1

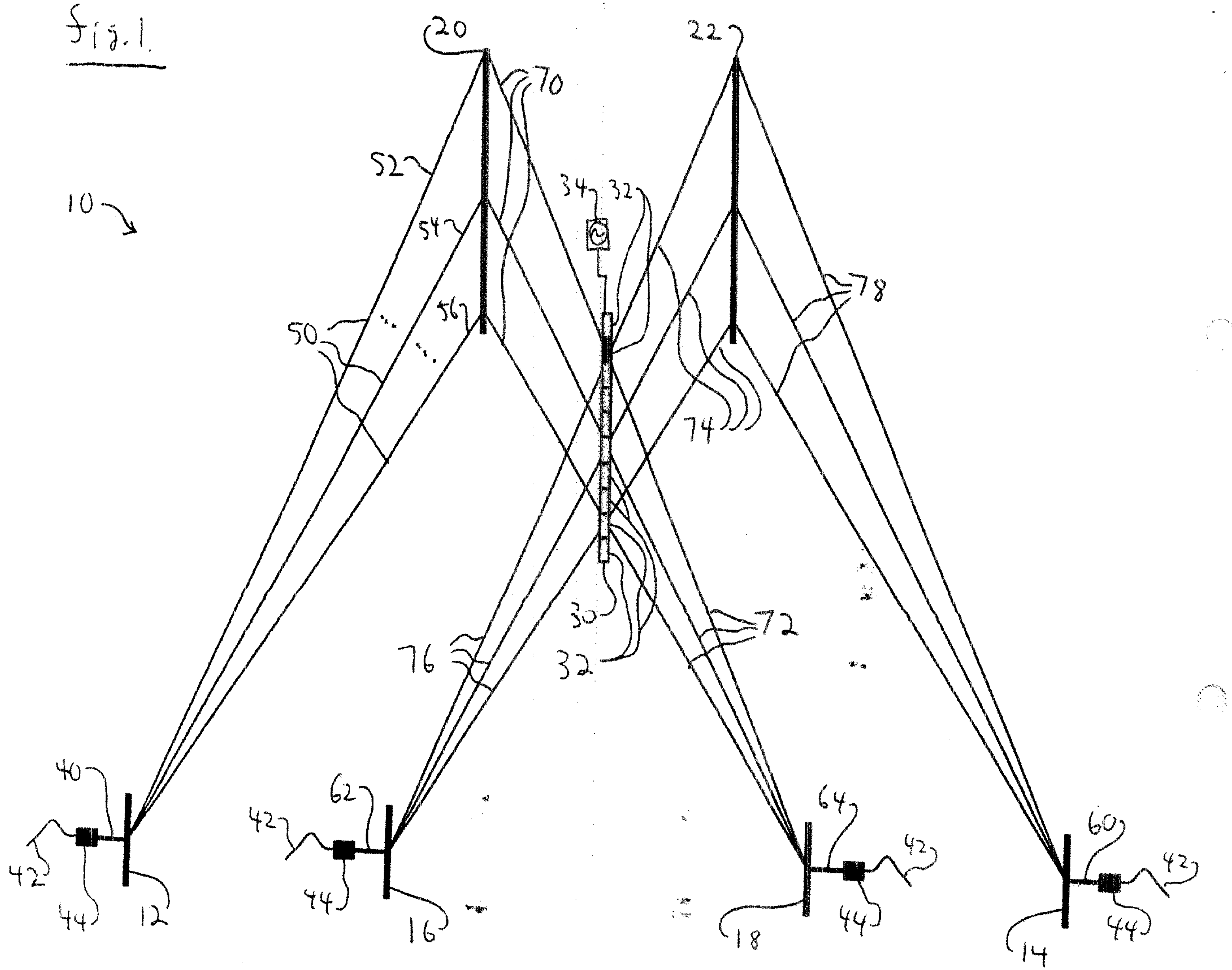


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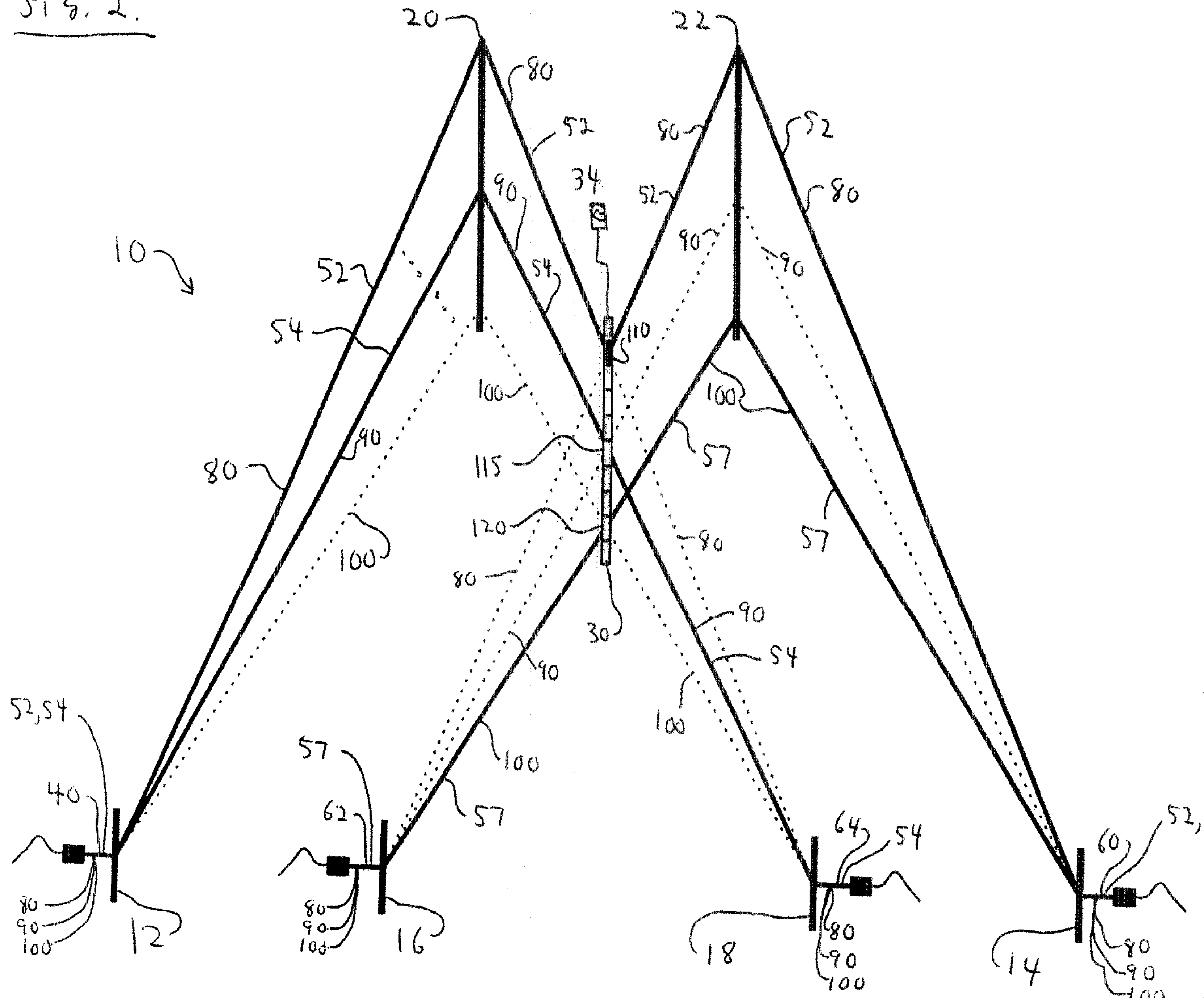
Fig. 2.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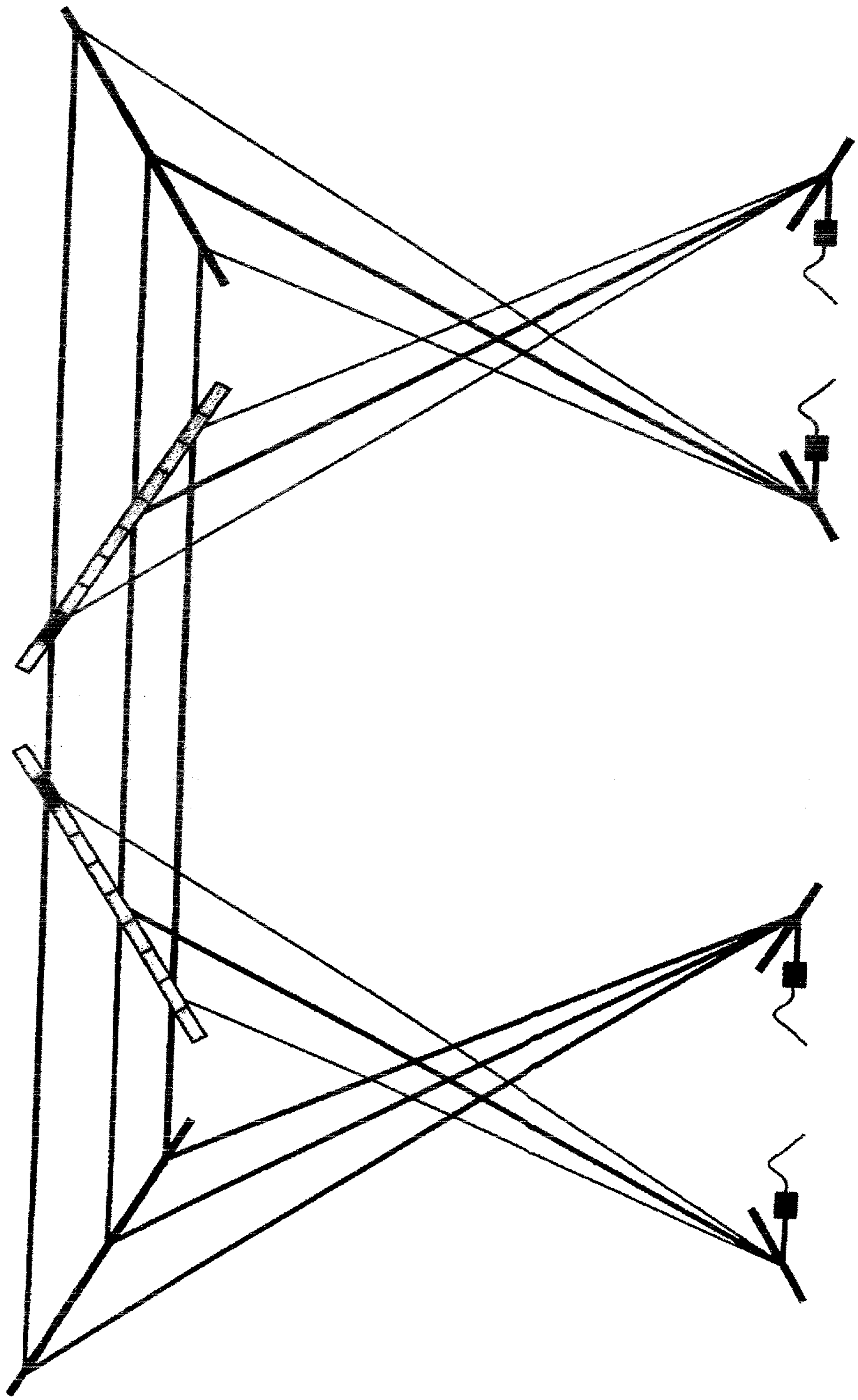

Fig. 3

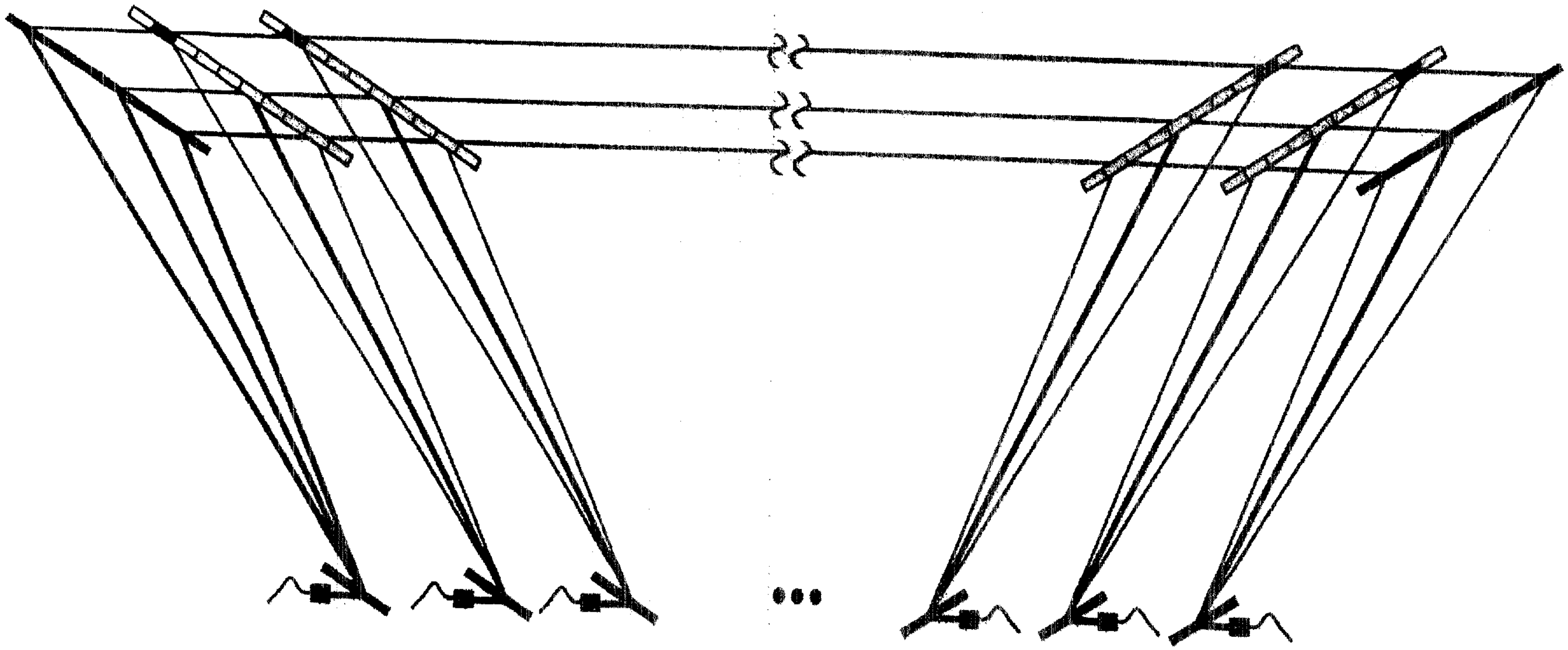

Fig. 4

Fig 5

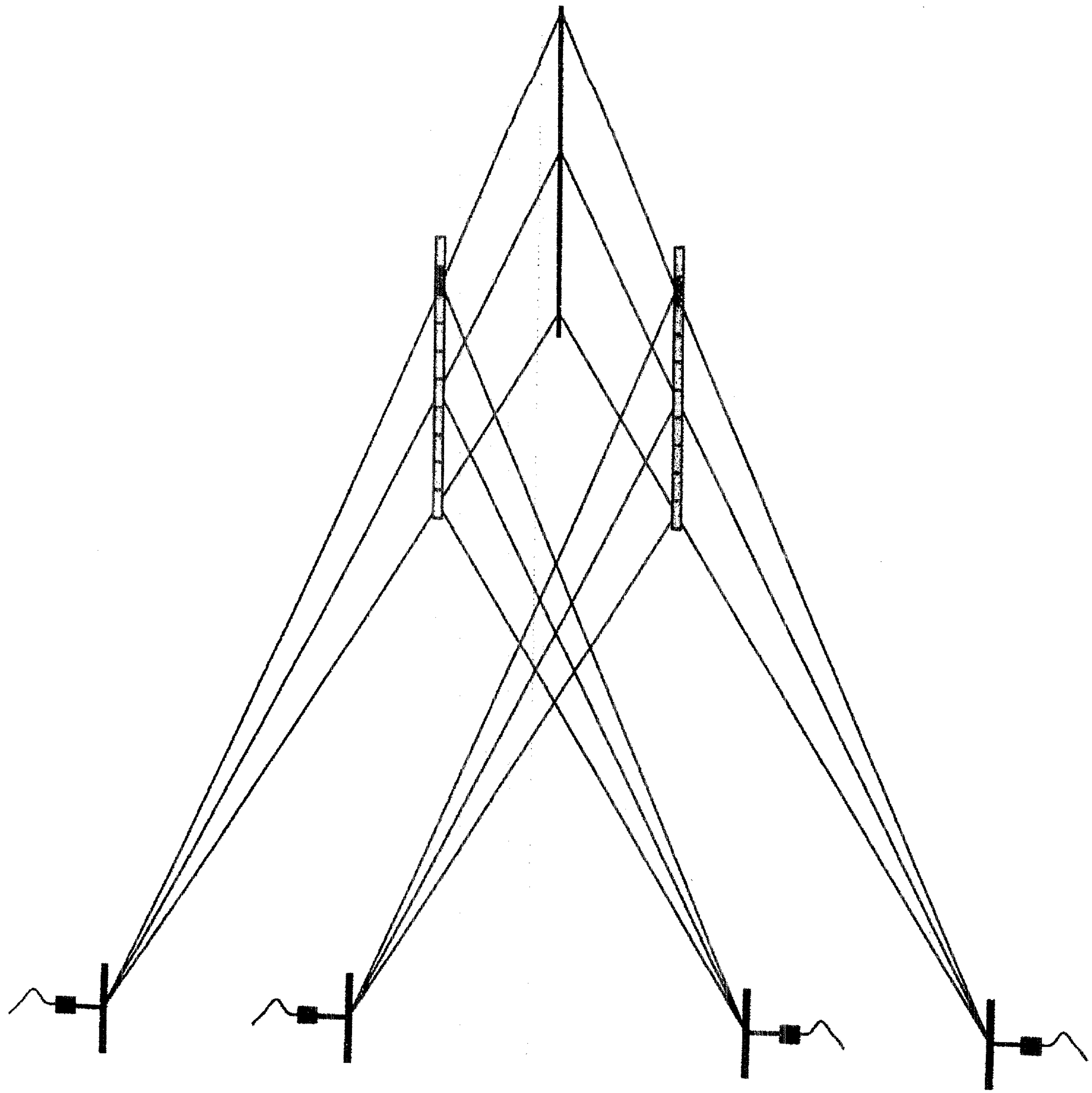

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Fig. 6.

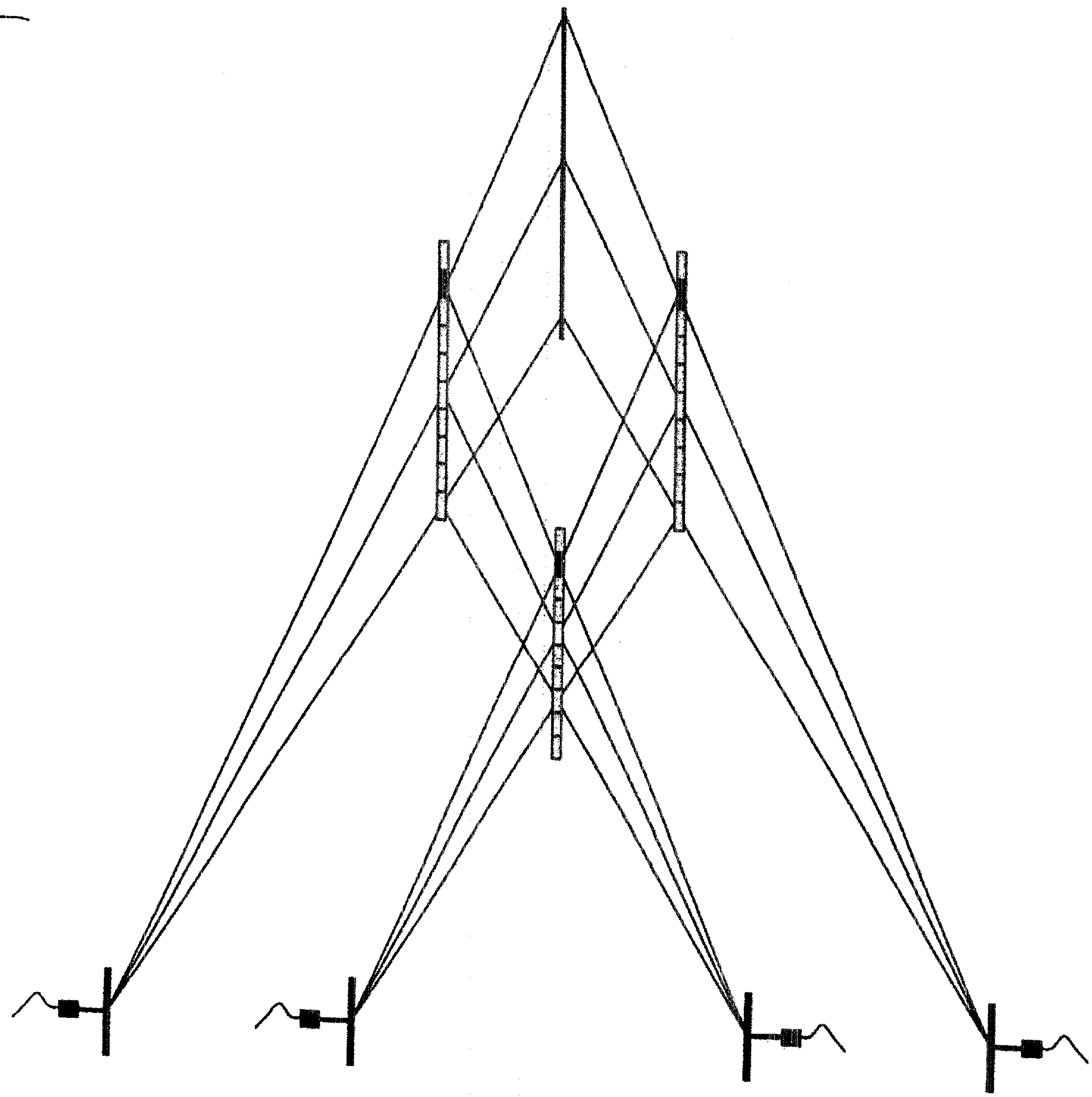
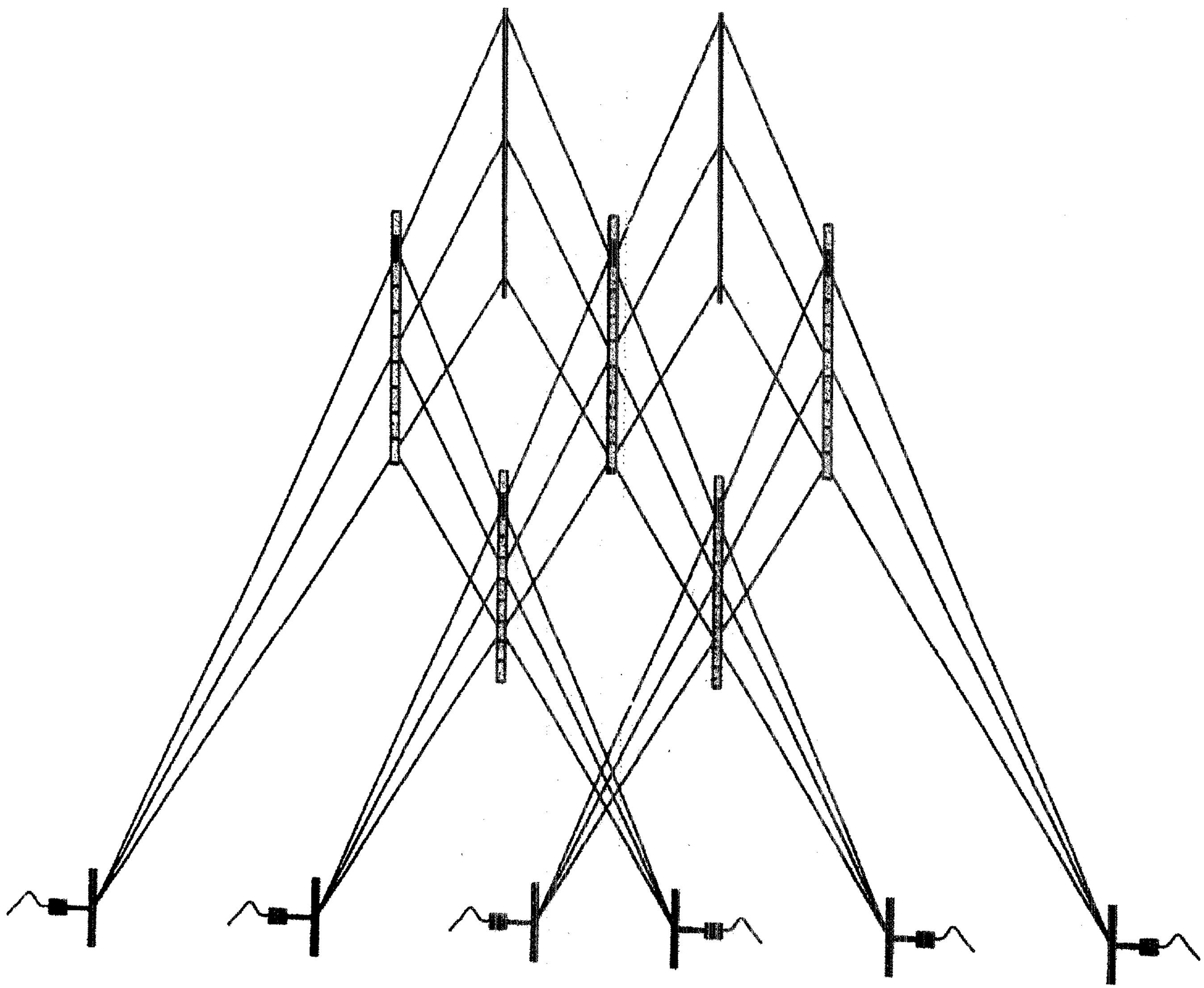


fig.7



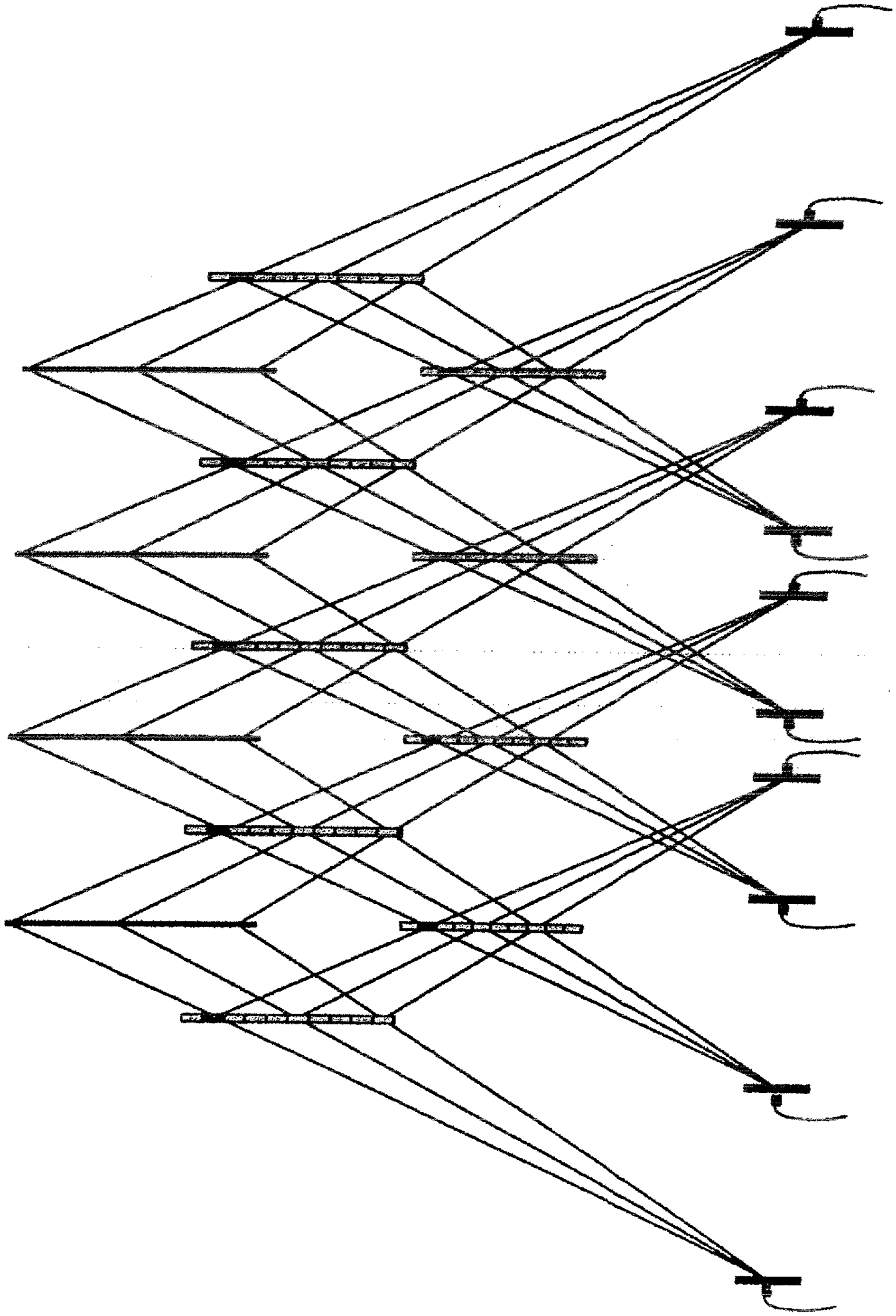


Fig. 8

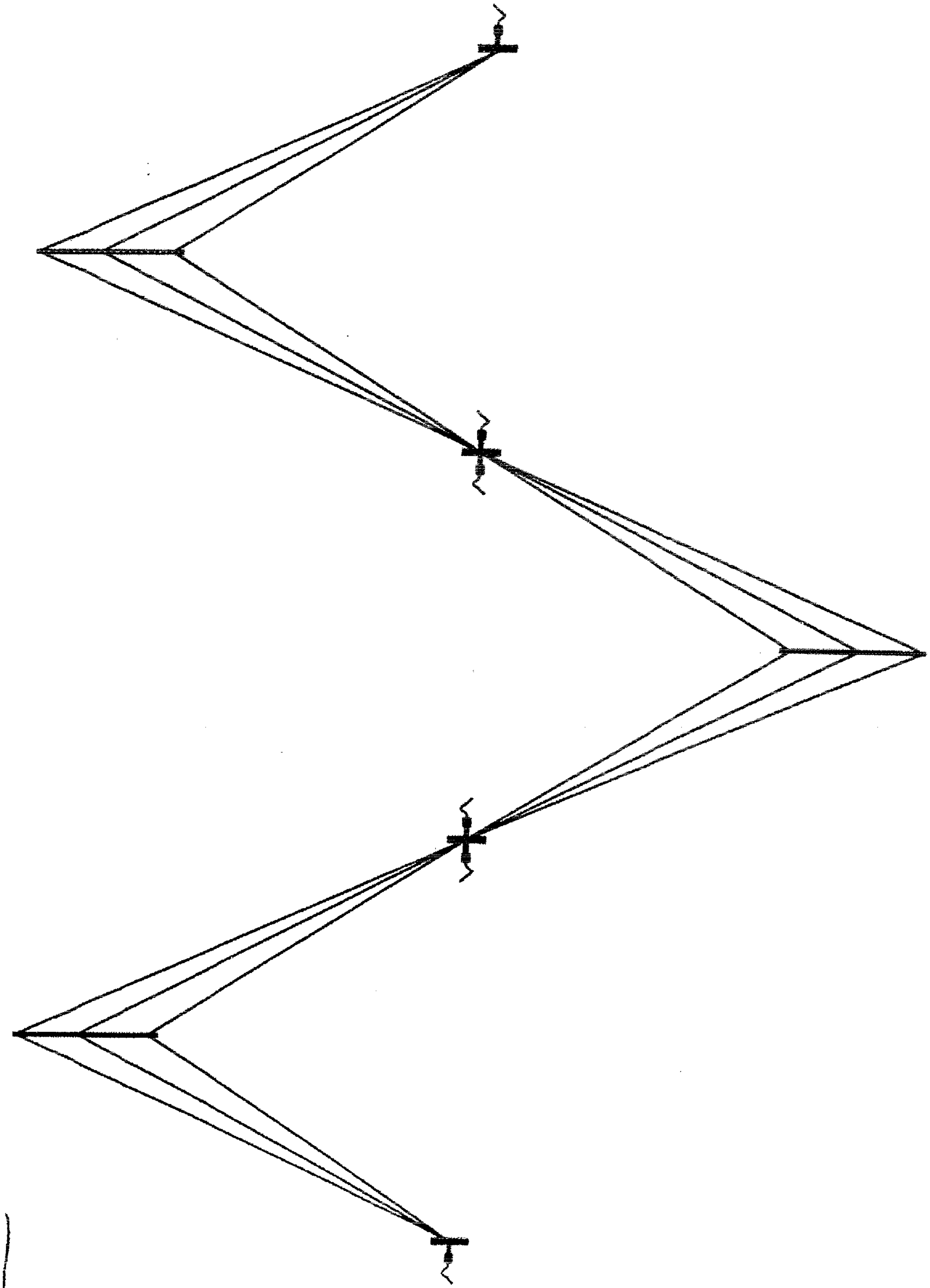


Fig. 9

Fig.10.

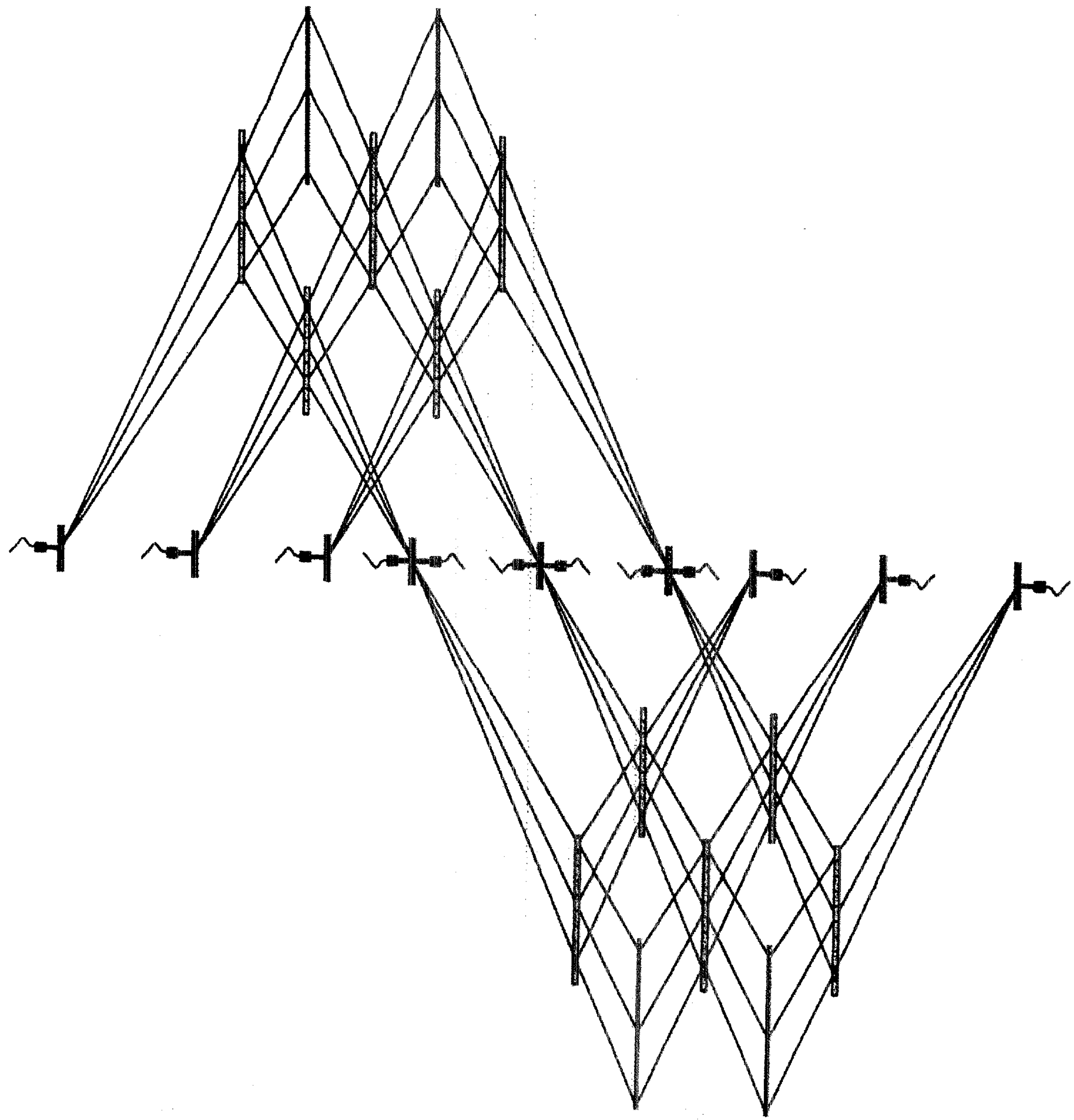


fig. 11

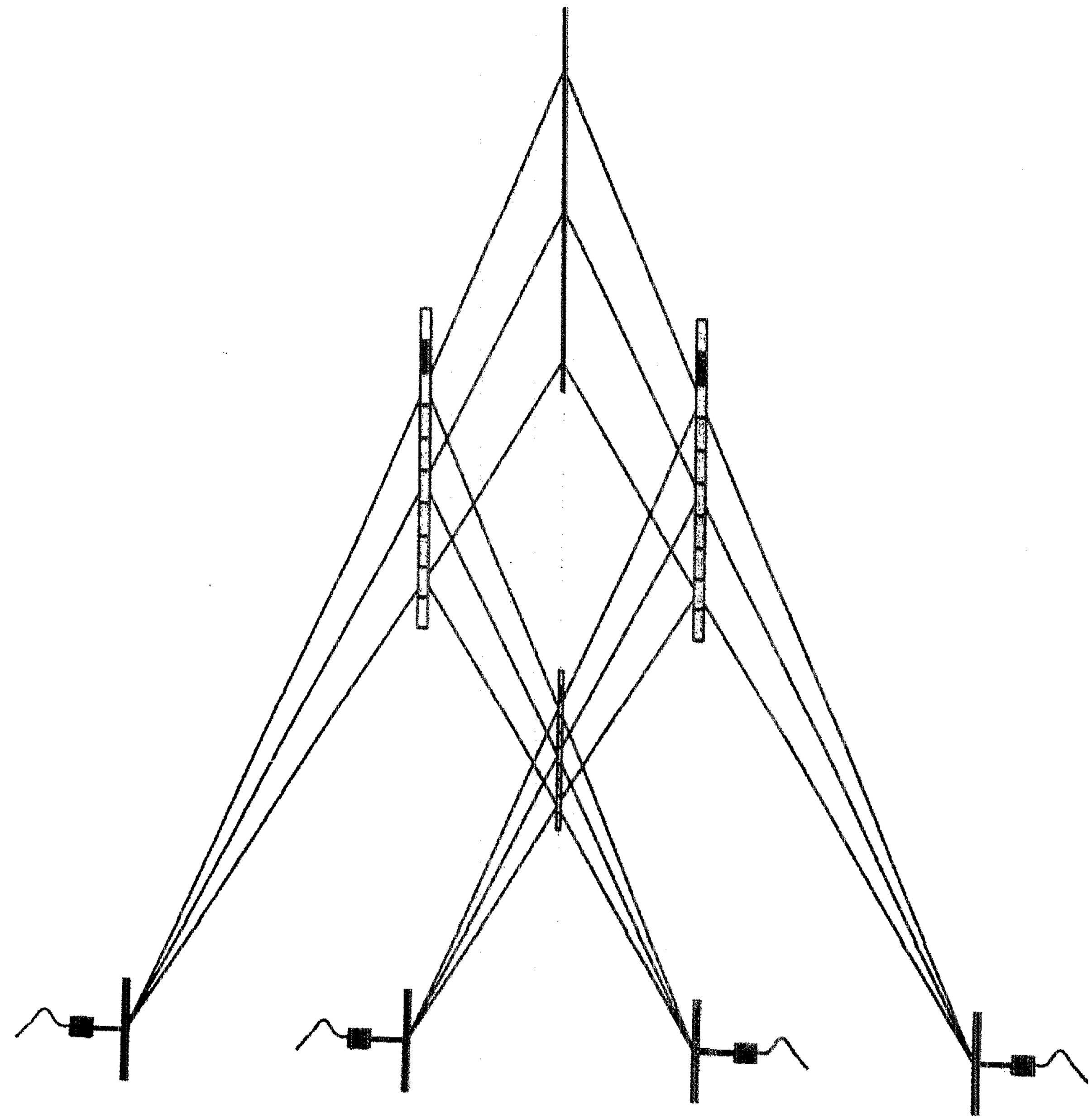


Fig.12

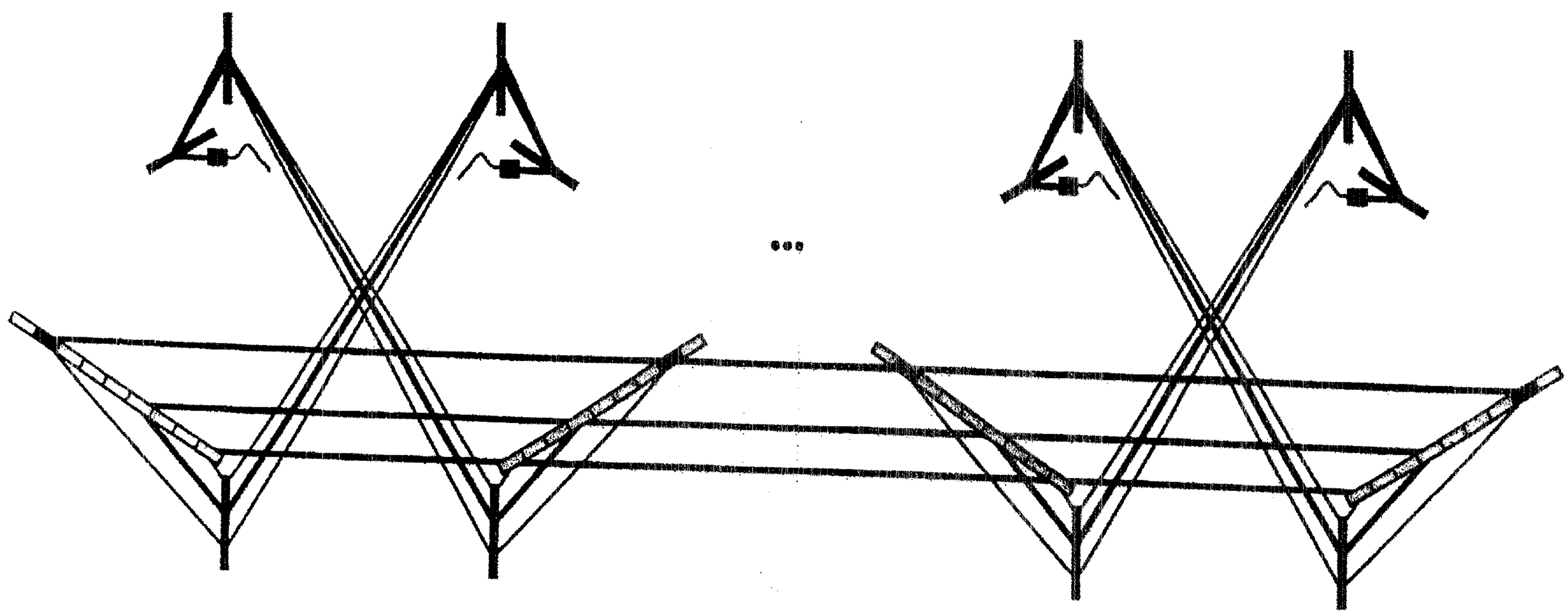


Fig. 13

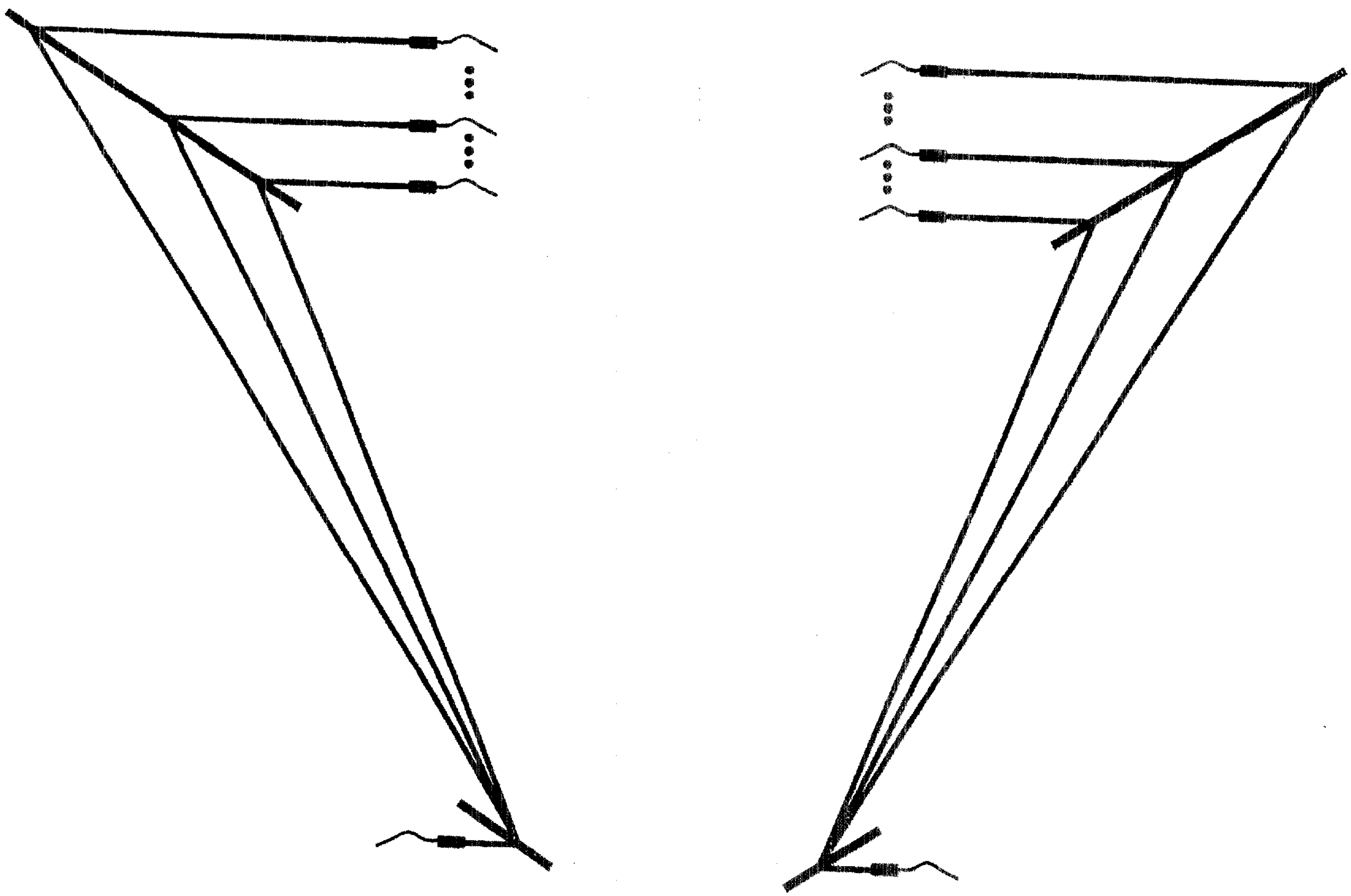


Fig. 14